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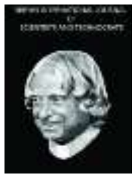

RESEARCH ARTICLE

Display Water Cooler

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ABSTRACT

Industries, colleges, restaurants, etc., includes canteens which use refrigerators, water coolers and air conditioners to generate heat during the process of refrigeration. This heat energy is usually wasted. But in this project, we have utilized this heat, to heat the water without an external source of power. The purpose of the project is that, the heated water can be utilized to wash hands and clean utensils in the canteens. Heating the water involves many types of sources like electric heaters, fire, etc. In this project, we use a water-cooled condenser as a heating source to heat the water. During the compression phase of the refrigerant, the refrigerant delivers large amount of heat. This heat is utilized and made as an external water-cooled condenser with a refrigerant coil in the refrigerator along with an air-cooled condenser as a sub-cooler. During this process of refrigeration, only the compressed refrigerant transfers the heat to the water, saves power and thereby produces hot water that finds it to have a good temperature sufficient enough to kill bacteria present in hand and also to wash the utensils in the canteens.

Keywords: Refrigerators, Water-cooled condenser, Air-cooled condenser, Compression phase, Refrigerant coil, Bacteria.

1. INTRODUCTION

The fundamental action of refrigeration is to transmit heat from one place to another in a well-organized way, through machine-driven action [1]. There exist other actions to drive the heat by means of magnetic energy, electrical energy, laser energy, etc. [2]. At first, the heat is transferred into the refrigerant through evaporator and the other actions performed after the primary step is,

- Heat is transferred into the condenser.
- Condenser transmits heat to a cooling medium, which may be water or outside air.

1.1. Condenser

The main functionality of a condenser is to change a constituent from a gaseous state to a liquid state by means of cooling process. This makes the substance to lose latent heat and thus it is transmitted to the coolant condenser. Condensers are chiefly employed to exchange heat, be it at a small range or at a very big range of industrial sized appliances adopted for plant processing [3]. The condenser in the refrigerator is to discard the heat that is removed from the inner surrounding of the refrigerator to the air medium outside. Condensers are used in systems that inter-change heat like,

- Air conditioners
- Industrial chemical processes like distillation [4].
- Steam power plants, etc. [5].

  The coolants used in the condenser are cooling water or circulating air.

In the project, display water cooler, which is depicted in the figure 1, is designed and fabricated using the expected calculations which provides the best output for heating the water, by using the above principles and the condenser working processes.

2. VAPOR COMPRESSION REFRIGERATION CYCLE

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In the Vapor-Compression Refrigeration System (VCRS), the refrigerant undertakes phase variations [6]. It is the best extensively utilized technique for buildings and automobiles air-conditioning. Its usage is also employed in domestic and commercial refrigerators. It is found to be useful in comprehensive depositories for ice-cold or packing of foods and meats at a freezing condition. It is also used in trucks that are refrigerated and in railroad cars, and in several commercial and industrial applications. Some of the industrial plants that make use of this technique are,

- Oil refinery plants.
- Petrochemical and chemical processing plants.
- Natural gas processing plants.

Refrigeration can be stated as reducing the surrounded temperature by eliminating the heat form that place and sending it somewhere else. Appliances like air conditioner, refrigerator, air source heat pump and geothermal heat pump/chiller heat pump does this operation.

This technique of vapor-compression uses a liquid refrigerant which circulates as a medium to suck and eliminate the heat [7]. The figure 1 shows a single-phase vapor compression system.

Figure 1.Display water cooler unit

These kinds of systems constitutes the following components like, a compressor, a condenser, a thermal expansion valve which is otherwise called as the throttle valve or metering device, and an evaporator [8].

The refrigerant that is circulating makes its way into the compressor. The state of the compressor is thermodynamic in nature as a saturated vapor. The refrigerant is thus compressed to a pressure which is high. This results in the increase in the temperature also. The compressed vapor which is hot, in a thermodynamic nature is also called as superheated vapor. Cooling water or cooling air that is made to flow across the coil or tubes condenses the hot compressed vapor which exhibits a particular pressure and a particular temperature. It is this place where the refrigerant that makes its circulation discards the heat from the system and this heat which is discarded is driven by means of water or air.

The liquid refrigerant that is condensed, possessing a thermodynamic state is also called as saturated liquid. This liquid is then channeled over an expansion valve. It is here it experiences a sudden pressure drop. This drop in the pressure causes an adiabatic flash evaporation of a portion of the liquid refrigerant [9]. This consequence of the auto-refrigeration lessens the liquid’s temperature and also reduces the temperature of the vapor refrigerant mixture to a temperature that is cooler than the surrounded refrigerated space.

The mixture which is cold is then channeled through evaporator’s tubes (coil). A fan is present to spread the air which is warm towards the surrounded area over the tubes (coil) that has the cold refrigerant liquid and vapor mixture. This air which is warm evaporates the cold refrigerant mixture’s liquid portion. Simultaneously, the air which is revolving is cooled and thereby the temperature of the surrounded area is reduced to an expected temperature. The action of evaporator to absorb and eliminate the heat that is discarded by the condenser, and to transfer this absorbed heat somewhere else happens at this moment by the help of water or air that is present in the condenser.

To reach the cycle of refrigeration [10], the refrigerant vapor from the evaporator which is a saturated vapor is re-circulated into compressor.

2.1. Phases of the VCRS Cycle

The VCRS cycle is encompassed of the 4 phases as discussed below. The figure 2 depicts the variations in pressure and volume

in every single section of the VCRS system [11].

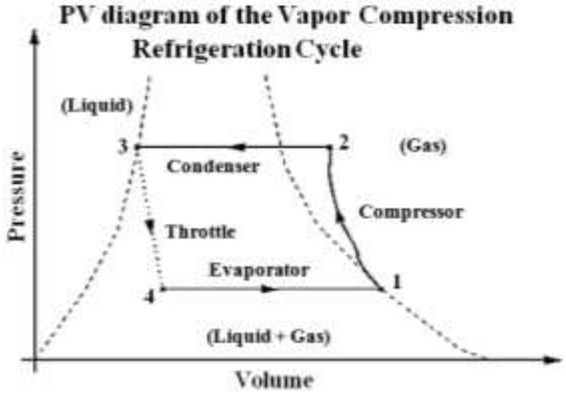

Figure 2.Changes in pressure and volume of VCRS

2.1.1. Compression phase

In the compression phase, the refrigerant makes its entry towards the compressor, like a gas which has lower pressure and lower temperature. After this the refrigerant undergoes adiabatic compression. During the compression that happens in an adiabatic fashion, the fluid that goes out of the compressor possesses an elevated level of pressure and temperature.

2.1.2. Condensation phase

In this phase, the gas that possesses a higher pressure and a higher temperature gives out the heat energy and gets condensed within the system's condenser section. The condenser is in touch with the refrigeration system's reservoir which is hot. It is due to the work that is externally added to the system, that the gas gives out heat to the hot reservoir. The refrigerant thus moves out having a liquid at high pressure.

2.1.3. Throttling phase

In this phase, the throttle valve gets enlarged with the help of the liquid refrigerant when it is pushed into the throttle valve. In this way, the refrigerant, though being in the liquid phase, possesses pressure and temperature to be at a lower rate. The throttle valve may be a slit which is thin in size or it can be a type of plug which has holes. The refrigerant experiences a minimized pressure when it is pushed via the throttle. This expands the liquid.

2.1.4. Evaporation phase

In this phase, the refrigerant exhibiting a lower pressure and temperature makes its path through the evaporator. This evaporator is actually in touch with the reservoir which is cold in nature. Since the pressure is continued to be low, low temperature is sufficient in boiling the refrigerant. This makes the liquid to absorb the heat from the reservoir which is cold, and finally the liquid vanishes through the process of evaporation. The refrigerant moves out of the evaporator like a gas that possesses a temperature and pressure which is of lower level [12]. This refrigerant is in turn fed once more into the compressor, again towards the start of the cycle.

2.2. Vapor compression cycle with water as inter cooler

2.2.1. Methodology

The diagrammatic representation of the VCRS having a diffuser at the inlet of the condenser is displayed in the figure A1. The system has dual flow lines [13]. One of the flow lines is of an ordinary VCRS type having no diffuser, while the other one has a diffuser with it. On the place of the diffuser outlet, a pressure gauge is fixed and also at the ordinary flow line, a pressure gauge is fixed. In both these outlets, the pressure gauges are fixed to measure the pressures in their respective places. Thereby the pressures can be calculated in the presence or in the absence of the diffuser. A fan is presented in the condenser to produce a sub cooling effect. The flow control valves control the opening or the closure of both the flow lines. A steady refrigeration outcome is regulated as long as the experimentation is in function. The experimentation is conducted with the help of the readings which are taken in the presence or in the absence of the diffuser. The experimentation results are then matched with one another. The graphical representation of pressure enthalpy chart is exhibited in figure 3.

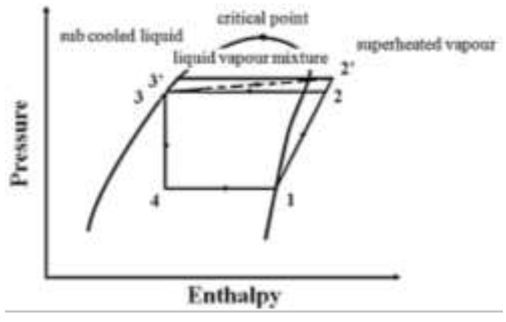

Figure 3.Pressure enthalpy chart of the system

The figure 3 displays the system's enthalpy chart with regard to the pressure. The pathway 1-2-3-4 displays the cycle of VCR with the absence of the diffuser. Likewise, the pathway 1-2'-3'-4 displays the VCR cycle with the presence of the diffuser at the inlet of the condenser. The Coefficient of Performance (COP) is calculated to measure the efficiency of the system [14 - 18].

The fundamental formula in common to find the value of COP whether the diffuser is used or not is given in equation (2.1).

$$\mathrm{COP} = \text{net refrigerating effect} / \text{work done} \quad (2.1)$$

The formula to calculate the COP when the diffuser is used is expressed in the equation (2.2).

$$\mathrm{COP} = (h1 - h4)/(h2 - h1) \quad (2.2)$$

The formula to calculate COP while the diffuser is unused is expressed in the equation (2.3)

$$\mathrm{COP} = (h1 - h4)/(h2' - h1) \quad (2.3)$$

As soon as the diffuser is started to be used, there is a drop in the pressure from point 2' to point 2. Thus the equation of COP becomes again like the one expressed in equation (2.2).

Therefore, the calculation of COP rise is expressed in the equation (2.4) as,

$$\{(h1 - h4)/(h2 - h1)\} - \{(h1 - h4)/(h2' - h1)\} \quad (2.4)$$

2.3. Refrigerant

A refrigerant which is generally a fluid is either a type of mixture or a type of substance. It is found to be helpful in heat pump and also in the refrigeration cycle. In majority of the cycles, the refrigerant makes a switch from a liquid phase to a gaseous phase and vice versa. Most of the working fluids make use of this principle [19]. In the twentieth century, fluorocarbons, particularly the chlorofluorocarbons, were found to be in a humdrum. However owing to the depletion effects that they cause in the ozone layer, they were ruled out of their usage [20, 21]. Some of the generally used refrigerants are ammonia, sulphur dioxide and propane (non-halogenated hydrocarbon). The best refrigerant [22-25] exhibits a positive thermodynamic nature, with features like [26, 27],

- Non-corrosive to mechanical parts
- Should be safe [28]
- Free from toxicity and flammability
- Does not cause ozone depletion [29]
- Does not cause changes in climate [30]

As many fluids possess the required qualities and behaviour in various aspects, the selection of liquids is an issue of substitution.

The most wanted thermodynamic properties must possess the qualities given below,

- The point of boiling of the liquid is to some extend be lower than that of the desired temperature.
- Elevated heat vaporization.
- Density in the liquid form should be reasonable.
- Density in gaseous form should be pretty higher.
- Critical temperature should be high.

The refrigerants can be used for applications that function at various pressure ranges as; pressure can cause an impact on their properties of boiling point and gas density [31, 32].

2.3.1. Common refrigerants

A few widely used refrigerants are,

- R-10 Carbon tetrachloride (Tetrachloromethane) - CCl_4
- R-134A 1,1,1,2-Tetrafluoroethane - $C_2H_2F_4$
- R-22 Chlorodifluoromethane - $CHClF_2$
- R-32 Difluoromethane - CH_2F_2
- R-40 Chloromethane - CH_3Cl

2.3.2. Refrigerant R134A

R134a is well-known as Tetrafluoro ethane (CF_3CH_2F). It originates from the HFC refrigerant hierarchy. As the refrigerants of CFCs and HCFCs cause a disastrous harm to the ozone, the refrigerant family of HFC was used extensively as a substitute to both the refrigerants of CFCs and HCFCs [33, 34].

These tetrafluoro ethanes are made use as a substitute, in support of R-12 CFC refrigerant in centrifugal and also as a substitute in rotary screw as well as in scroll and reciprocating compressors. Usually it is not dangerous to handle because it has the properties of non-toxicity, non-flammability and it is non-corrosive too.

At the present scenario, its application

is found in air conditioning systems in automobile vehicles. It is used in plastic foam blowing in manufacturing industry and also it is used as a propellant in pharmaceuticals industry.

It remains in a gaseous state soon after the exposure to the environment because the required temperature for it to boil is -14.9°F or -26.1°C [35, 36].

This refrigerant is not at all well-suited with the lubricants and not at all well-suited with mineral based refrigerant that is at present utilized in R-12. To utilize this refrigerant, the design of the condenser and evaporator must be modified. To achieve the above criterion, hoses that are small in size and a thirty per cent of surge in control pressure guideline must be adapted in the system [37].

2.3.2.1. Properties of R134A

- Boiling point is of -14.9°F or -26.1°C.
- Auto-ignition temperature is of 1418°F or 770°C.
- Ozone depletion is of 0 level.
- Solubility in water is of 0.11% by weight at 77°F or 25°C of temperature.
- Critical temperature is of 252°F or 122°C.
- Cylinder color code is light blue.
- Global Warming Potential (GWP) is 1200.

3. CALCULATION OF COP

Let,

T_1=24 °C = 297 K
T_2=90° C= 363K
T_3= 50° C = 302.4 K
T_4= 29.4°C=279 K

Let,

H_1= 82.9 kj/kg
H_2 = 82.9 kj/kg
H_3 = 121.465 kj/kg
H_3'= 90.05kj /kg
H_4 = 58.4 kj/kg

The formula to calculate the work done is expressed in equation (3.1) and thus the work done is calculated as,

$$\text{Work done} = H_2 - H_1 \tag{3.1}$$

=193.69 – 82.9
=110.79 KJ/KG

The formula to find the heat rejected is given in the equation (3.2). And thus the heat rejected is measured as shown below.

$$Q_{\text{REJECTED}} = (H_2 - H_3) + (H_3 - H_3') \tag{3.2}$$

= (192.69-121.465)+(121.465-90.5)
= 103.24 KJ/KG

The formula to find the heat supplied is given by the equation (3.3). Using this, the heat supplied is calculated as,

$$Q_{\text{SUPPLIED}} = H_1 - H_4 \tag{3.3}$$

= 82.9 - 58.4
= 24.5 KJ/KG

The formula to find the COP is given in equation (3.4) and thus COP is calculated as,

$$\text{COP} = \text{TH}/\text{TH} - \text{T} \tag{3.4}$$

= 363/363-279
= 4.3

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APPENDIX

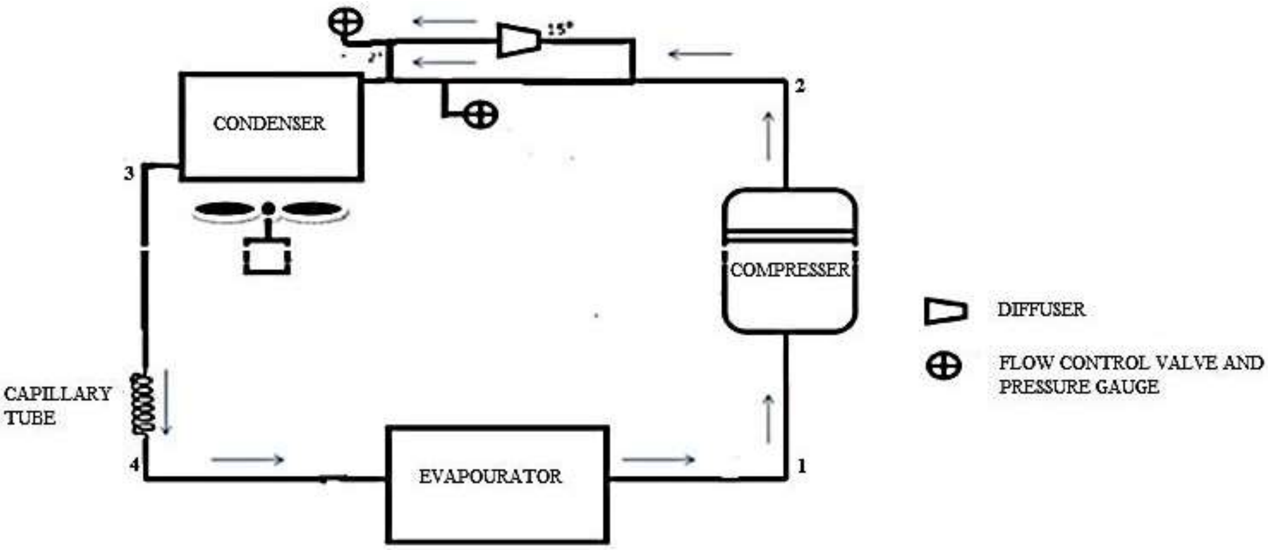

Figure A1.The schematic diagram of the vapor compression refrigeration system